Gamma Radiation Treatment for Disinfestation of the Mediterranean Fruit Fly in California Grown Fruits. I. Stone Fruits[1,2]

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ABSTRACT

A study was conducted to investigate the effectiveness of gamma irradiation for disinfesting California grown stone fruits which contain eggs and larvae of the Mediterranean fruit fly, *C. capitata*. Several varieties of plums, peaches, and nectarines, and one variety each of cherries and apricots were investigated. It was found that the different varieties of fruits as well as fruit quality, i.e., ripeness, water content, bruised areas on the fruit, may have a pronounced effect on the effectiveness of the gamma radiation treatment. However, despite varying degrees of survival due to fruit quality, in all of the egg hatchability and larval survival studies, none of the treated individuals survived to emerge as adults at dosages less than 0.60 kGy. Our studies indicate that the gamma radiation technology might indeed be considered a possible alternative to quarantine treatment with chemical fumigants such as ethylene dibromide (EDB).

The discovery of Mediterranean fruit flies, *Ceratitis capitata* (Wiedemann) in California on June 5, 1980, two in Santa Clara County and one 400 miles away in Los Angeles County, initiated a large scale eradication effort in the State of California. This event together with the continued controversy over the use of ethylene dibromide (EDB) as a pesticidal fumigant set into motion renewed efforts for the development of alternative technology for postharvest treatment of export fruit and vegetable commodities. Although EDB is still considered one of the most effective fumigants for various fresh fruits and vegetables, it is also highly controversial because studies have implicated EDB as potentially carcinogenic and mutagenic. In fact, the federal Environmental Protection Agency (EPA) has proposed the suspension of using EDB as a fumigant for citrus and other fruits by mid-1983.

Much research has already been completed on the use of gamma irradiation to satisfy quarantine restrictions on export commodities (e.g., Burditt et al. 1971; Balock et al. 1956; Balock et al. 1963; Balock et al. 1966). However, implementation of this technology has been stymied due to governmental regulations restricting use of "food additives" in certain fresh food commodities. In late 1980, a joint committee of the Food and Agriculture Organization (FAO), the International Atomic Energy Agency (IAEA), and the World Health Organization (WHO) declared that irradiation of any food commodity up to 10 kGy would be safe for human consumption. Subsequently, the U.S. Food and Drug Administration (FDA) is now considering a proposal to declare any food irradiated up to 1 kGY as being wholesome and safe for human consumption. The proposed recommendation by the FDA is certainly conservative relative to the declaration by the FAO/IAEA/WHO committee. However, it is a major step forward in promoting the development of the gamma irradiation technology for postharvest treatment of export commodities.

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While most of the previous studies on the use of gamma irradiation for disinfestation were conducted on tropical and subtropical fruits such as papayas and avocados, few studies report on the effectiveness of radiation on temperate fruits and vegetables (Moy et al. 1983). The recent outbreak of the medfly in California and the possibility of an infestation affecting the multibillion dollar fresh fruit industry rejuvenated interest in the potential of gamma irradiation as an alternative to EDB treatment. The advantages of quarantine treatment with gamma radiation over EDB is twofold: 1) it assures complete disinfestation without leaving any harmful residues, and 2) in most fruits, it will delay the ripening process and therefore increase the marketable shelf life of the commodity. Treatment with EDB on the other hand, results in harmful residues within the fruits as well as accelerate the ripening process.

In this paper, we report results of research conducted in response to a call for additional data on the effectiveness of gamma irradiation for disinfesting California grown stone fruits which contain eggs and larvae of the Mediterranean fruit fly. Several varieties of plums, nectarines, and peaches, and one variety each of cherries and apricots were investigated. We have also completed similar studies involving citrus (Navel oranges and Calfame lemons), pome fruits (apples and pears), tomatoes, grapes, persimmons and kiwifruit. The results of these studies will be presented in separate papers. Preliminary results of the effects of gamma irradiation on fruit quality of the stone fruits are presented in Moy et al. (1983) and therefore are not presented in this paper.

MATERIALS AND METHODS

Two strains of medflies were established in our laboratory; one was established from adults obtained from the United States Department of Agriculture (USDA) Agricultural Research Service (ARS) Tropical Fruit and Vegetable Research Laboratory in Hawaii, while the second strain was established from adults reared out of the Jerusalem cherry fruits *(Solanum pseudocapsicum)* collected from the Volcanoes National Park on the island of Hawaii. The former will henceforth be referred to as the "USDA strain" while the latter will be referred to as the "wild strain". The two strains were maintained in 122 cm × 61 cm × 61 cm cages which were enclosed on four sides (front, top and the two sides) with fine mesh aluminum screen. The back of the cages were enclosed by glass plates on the upper half and wooden panels on the lower half. Also, two 18 cm diameter portholes were cut out of the wooden panel and one end of 45 cm lengths of elastic surgical stockinettes were attached to each porthole to allow easy access into the cages while minimizing medfly adults from escaping.

In our early experiments with the stone fruits, we concentrated our efforts with the wild strain with the rationale that any bias which may have been incorporated in the USDA strain (which had been maintained in the laboratory for more than 300 generations without incorporation of new genetic material from the natural population) would be excluded from our studies. By using the wild strain, the data we obtained would more likely reflect results which would be obtained with fruits which were infested in the field. We attempted to maintain the genetic integrity of the natural population by supplementing our wild strain with adults reared from field collected substrates every two or three generations. This system worked well for about six months when natural substrates were plentiful and the medfly population in the field was large. However, when the natural population declined and flies became less available, it became extremely difficult to maintain our wild strain in the laboratory until finally it became impractical to continue to use this strain for the remainder of our studies. We can only attribute inbreeding depression and genetic deterioration as possible explanations for the decline of our wild strain. Thus, the experiments conducted during July - December, 1981 were completed using the wild strain while the USDA strain was used for experiments conducted during January - December, 1982.

The first set of experiments on the stone fruits were conducted to determine hatch rate of medfly eggs treated with various dosages of gamma radiation at various stages of development (i.e., 0-4, 24-28, 48-52, 64-68, 68-72, and 72-78 hours after the eggs were laid.). These experiments were conducted to determine the age at which medfly eggs were most resistant to treatment with irradiation. The results of these experiments are presented in Tables 1, 2, and 3. Once this was determined, we concentrated our efforts in studying hatchability of eggs treated at the most resistant age since dosages determined to be lethal for the most resistant age would logically be lethal for all eggs in any other stage of development.

For the egg hatchability studies, fruits were placed into cages with mature medfly adults and females were allowed to oviposit for four hours. The fruits were then removed from the cages and held at 70°F for varying lengths of time depending on the ages at which the eggs would be treated with radiation. With the eggs in situ, the fruits were then irradiated at various dosages with a Cobalt-60 gamma radiation source located on the Manoa Campus of the University of Hawaii. The dose rate at the time of our experiments was in the range of 0.055 - 0.045 kGy/min. Chadwich et al. (1977) indicated that the previously used unit of absorbed dose of radiation, the "rad", will be phased out by 1986 and will be replaced by a new unit of measure derived by the International System of Units. The amount of energy absorbed per unit mass of irradiated matter will henceforth be measured in grays (Gy) which is equivalent to 100 rad. Thus, 1 kilorad equals 10 Gy or 0.01 kiloGy (kGy).

Following treatment with radiation, 100 - 500 eggs (depending on the size of the fruit) were carefully dissected out of each fruit and placed on moist green blotting paper (5 cm × 5 cm) in rows of 5 eggs each. This method facilitated the tabulation of numbers of eggs which hatched in the control and treated samples. Each piece of moistened blotting paper was placed in a petri dish to prevent desiccation of the eggs. The number of eggs which hatched was recorded daily and first instar larvae which did hatch were placed on small slices of fruit or artificial medium (Tanaka et al. 1969) to observe further development. The egg hatchability data are presented in Tables 5, 6, and 7.

During the early phases of our studies, we observed that when eggs were oviposited in the various stone fruits, there may be slightly different conditions surrounding the eggs depending on the type and condition of the fruit. Eggs are usually oviposited in a dry hollow cavity beneath the skin of the fruits but in some cases, e.g., in most of the plum varieties or in other stone fruits which are overripe or bruised, the eggs may be partially or wholly submerged in liquid from the fruit. We therefore conducted a preliminary experiment to determine whether the two different conditions, "dry" or "wet", might have an affect on the radiation treatment. Two sets of 1000 medfly eggs each were placed on slightly moistened ("Dry") blotting paper in petri dishes. One set was retained as "Dry" Control while the other set was treated with 0.5 kGy of radiation. A third set of 1000 eggs was plated on blotting paper saturated with water and set aside as "Wet" Control. Another set of 1000 eggs was placed in a 50 mm × 6 mm culture vial filled with distilled water, irradiated in 0.5 kGy, and then plated out onto moistened blotting paper. Still another set of eggs (500) was placed in a vial of physiological saline, irradiated at 0.5 kGy, and again plated onto moistened blotting paper. The results of this experiment is shown in Table 4.

In addition to the experiments to determine dose levels required to result in non-hatch of medfly eggs, we conducted experiments to determine dosage/mortality in the larval stages of the medfly. Once again, our early experiments were focused on determining the most resistant of the larval stages. This was done by treating various ages of larvae with different doses of radiation and our findings confirmed the report of Balock et al. (1963) that the last instar larvae were indeed the most resistant to treatment with gamma radiation. Thus, we completed the larval survival experiments using the most resistant of the larval stages whenever possible. The procedures for these studies are as follows. Eggs were obtained from our USDA strain and placed on moistened blotting paper. After incubation at 21°C for 96 hours, the newly hatched first instar larvae were carefully picked up with a "00" camel's hair brush and implanted into holes prepared with a dissecting needle in the various stone fruits. The number of larvae which were implanted varied with the size of the fruit which were relatively constant within each type of stone fruit. For example, 50 larvae were implanted into each fruit of nectarines and peaches, 30 were implanted into plums, 15 into apricots and 5 into each of the cherries. The stage at which the larvae were treated was determined by dissecting one of the control fruits and examining the stage of larval development (Hardy 1949) in these fruits. If most of the larvae had attained the third and last larval instar in the control fruits, then the other fruits with larvae at the same developmental stage were treated with varying dosages to determine the minimum absorbed dose required to prevent pupation and/or emergence of adults. Following the radiation treatment, the fruits were maintained on a 28 cm × 40.5 cm wood-framed, ¼" mesh galvanized hardware cloth which was placed inside of a 49.5 cm × 31.8 cm × 15.2 cm fiberglass rearing box. Dry fine-grained vermiculite was placed in the bottom of the rearing boxes to serve as a pupation medium. Once all of the surviving larvae drop into the vermiculite, the fruits were inspected to be sure that no more larvae remained. The decomposed fruits were then discarded. The pupae were sifted and separated from the vermiculite and retained in a pint-sized paper container for adult eclosion.

RESULTS AND DISCUSSION

Egg Hatchability

Tables 1, 2, and 3 contain results of experiments designed to determine the age at which medfly eggs are most resistant to gamma irradiation when four varieties of nectarines, three varieties of peaches, and one variety of plums are used as ovipositional substrates. Clearly, the more mature the egg stage, the more resistant it is to the radiation treatment. These data confirm the findings of Balock et al. (1963) that the highest dose level was required to prevent hatch of eggs treated a few hours prior to hatching. At 20°-21°C, medfly eggs begin to hatch after about 96 hours and most will have hatched within 4 - 6 hours following the first hatch. Thus, to be assured that we were treating the most mature eggs without having hatched, we decided to conduct the remainder of our experiments on eggs which were 72 - 76 hours old.

There has been some discussion over the criteria used by the USDA Animal and Plant Health Inspection Agency (APHIS) in determining the security level required to permit transport of commodities from quarantine areas into fruit fly free areas. The concept of probit 9 in which treatment of food commodities result in 99.9968% mortality of the fruit flies is the currently accepted security level for quarantine purposes. At this level, 3.2 survivors are permitted to emerge as adults from a possible

100,000 eggs. The USDA Hawaii Fruit Fly Investigation Laboratory determined that .26 kGy was the minimum absorbed dose required to prevent adult emergence of the three species of fruit flies in Hawaii: the Oriental fruit fly, *Dacus dorsalis* Hendel; the melon fly, *Dacus cucurbitae* Coquillett; as well as the Mediterranean fruit fly (Burditt 1982). However, at dosages even higher than the .26 kGy proposed by the USDA studies, we observed a relatively high rate of egg hatch, sometimes upwards of 50% egg hatch in the Sun Grand nectarines (Table 5). Some of the larvae which hatch may develop into large third instar larvae and thus decrease the marketability of the fruits. Furthermore, there is some uncertainty whether fruit importing countries would accept fruits with any living larvae in the shipment. Therefore, most of our research involved determination of the minimum absorbed dosages required to cause mortality in the mature eggs and larvae of the medfly in stone fruits rather than relying on the criteria of non-emergence of adults at the probit 9 security level.

Data on hatchability of medfly eggs laid in eight varieties of nectarines after treatment with 0.4, 0.5, and 0.6 kGy of radiation are presented in Table 5. In all of the varieties tested, 0.6 kGy was certainly sufficient radiation to prevent 99% of the eggs from hatching. At the 0.6 kGy level, the highest hatch rate was observed in the Summer Grand variety at 1.69% while none out of 1500 eggs in the Autumn Gold, Flamekist, and Fairlane varieties hatched after treatment with 0.6 kGy of radiation. At the 0.4 and 0.5 kGy levels however, there were wide ranges in the hatch rate among the different varieties (see Table 5). Much of the variation we observed in egg hatch rate when fruits were treated at the 0.4 and 0.5 kGy levels may have been due to the condition of the fruits (e.g., ripeness, texture, water content, etc.), or possibly to slight variation in the age of the eggs at the time of the treatment. We found that, especially with fruits with high water content, fruit condition may be an important factor in assessing dosage/mortality levels when considering gamma radiation as a potential postharvest treatment for different varieties of fruits. We will discuss this further when we present our findings in the studies with the plum varieties. Perhaps, the most important bit of data to consider from the standpoint of use of gamma irradiation treatment for quarantine purposes, is the number of larvae which developed to pupae and actually emerged as adults. In all cases with the nectarine varieties, there were no larvae which developed to the pupal stage. Most of them died soon after hatching, with very few reaching the second larval instar. The numbers recorded under the column "partially hatched" in Table 5, indicate the number of individuals which died still partially encased within the chorion of the eggs.

Hatchability of eggs laid in two varieties of peaches is presented in Table 6. The results are similar to those obtained for the nectarine varieties. Again, hatch rate was reduced when the eggs were treated at the 0.5 and 0.6 kGy levels of radiation. At the 0.4 kGy dose, slightly more than 12% of the eggs laid in the Fay Alberta variety hatched while less than 1% of the eggs laid in the O'Henry variety hatched. As with the nectarines, none of the larvae which did hatch from the treated samples survived to pupate and most died soon after hatching.

Hatchability of eggs laid in apricots and Burlat cherries is also presented in Table 6. When cherries infested with medfly eggs are radiated at a dosage of 0.6 kGy, only 0.3% of the eggs hatched while nearly 7% hatched when treated with 0.4 kGy. Eggs laid in apricots however, hatched at a rate slightly higher than 1% at 0.4 - 0.6 kGy. Again, none of the larvae from the treated samples survived to the pupal stage.

The data obtained for five varieties of plums are presented in Table 7. Unlike the results we obtained for nectarine, peach, apricot and cherry, the hatch rate after treatment with 0.6 kGy was considerably higher. As high as 15% - 16% hatch for the

Friar and Laroda varieties were obtained after treatment with 0.6 kGy, while as high as 52% hatch was obtained in Kelsey plums after treatment with 0.5 kGy. We do not understand the exact reason for the high hatch rate in the plum varieties. High water content in some fruits may have a buffering effect on gamma irradiation as indicated in earlier discussion and may explain the high hatch in plums.

It may be appropriate at this point to discuss the results of a preliminary experiment to determine whether certain conditions, e.g., medfly eggs being submerged in a liquid, might have an affect on treatment with gamma irradiation. When the medfly female oviposits her eggs into most varieties of stone fruits except for those of plums, the eggs are encapsulated in a dry cavity a few millimeters below the skin. In the plum varieties however, the eggs are usually submerged in a pool of liquid due to the high water content in these fruits. It appears that plums do not react to the ovipositional punctures of the medfly female by producing a dry cavity around the eggs. Although the mechanism for the difference between the plum and the other stone fruit varieties is not known, our impression is that when the eggs are surrounded by some kind of liquid, the effects of the gamma irradiation treatment are buffered to a certain extent. In Table 4, we present the results of an experiment to determine whether water in which medfly eggs may be submerged within the ovipositional cavity can have an effect on the amount of radiation received by the eggs. The data clearly indicate that eggs submerged in water are buffered from the effects of the radiation. At the 0.5 kGy level, only 0.3% of the eggs hatched when treated under "dry" (moist blotting paper) conditions. However, when the eggs were placed in a small vial of water or physiological saline and then treated with 0.5 kGy of radiation, nearly 85% of the eggs hatched. Thus, we suspect that the condition of the fruit, i.e., high water content, overripeness, or bruised areas which may cause the eggs to be partially or wholly submerged in liquid, may have a bearing on the effectiveness of the radiation treatment.

Larval Survival

Results of the larval survival studies are presented in Tables 8 - 10. Inspection of the data indicate considerable variation in the rate of larval survival among the different varieties of fruits. For example, among the nectarine varieties, only 24.8% of the untreated (Control) larvae pupated while 73% pupated in the Red Grand variety. In the plums, 0 out of 510 larvae implanted into the Casselman variety developed to pupation, while 39.3% pupated in the Laroda variety. We speculate that some of the differences in larval survival may be due to the high water content in some of these fruits. For example, in the Casselman plums, many large (2nd and 3rd instar) larvae were found dead inside the fruit, possibly due to drowning. In a pilot experiment, when fruits with "waxy" skin are split open to allow drainage of liquid which accumulates during decomposition, survival rates of larvae were found to be much higher (unpublished data). When third (and a few late second) instar larvae which are feeding within the Autumn Gold variety of nectarines are treated with 0.5 kGy of radiation, 33% of the larvae survived to pupate, while in the Flamekist variety, less than 21% pupated. In both the Casselman and President plums, slightly more than 1% pupated following treatment with 0.5 kGy. At a dosage of 0.6 kGy, nearly 24% of the larvae in the Fay Alberta variety of peaches and 32% of the larvae in the Red Grand variety of nectarines survived to pupation. With the exception of two cases, no adults emerged following treatment at either the 0.5 kGy dosages. In the two cases, one male and one female fly emerged from fruits treated with 0.6 kGy (Sun Grand nectarines) and 0.5 kGy (Kelsey plums) respectively. Dissection of the male revealed fully developed testes as well as motile spermatozoa. The female when mated to a laboratory-reared male produced normal progeny. Based on these observations, we suspect that these fruits were accidentally infested by flies after the irradiation treatment.

Despite the wide range of variability in larval survival at least to the pupal stage, the data clearly indicate the effectiveness of the radiation treatment in preventing adult eclosion. We should remind the reader again that all of these experiments were conducted on the most resistant of the larval stages. Larvae at any other stage of development which may be infesting the fruits would certainly be killed at the 0.5 and 0.6 kGy dosages.

SUMMARY AND CONCLUSIONS

The probable ban of EDB as a fumigant for fresh fruits and vegetables generated renewed interest in the gamma irradiation technology as an alternative treatment for disinfesting export commodities. The primary goals of our research were to determine minimum absorbed dosages of gamma irradiation required to prevent egg hatch as well as emergence of adults when mature larvae are treated in stone fruits infested with the Mediterranean fruit fly.

The results of our egg hatchability studies indicate that fruit condition, i.e., ripeness, water content, etc., at the time of the treatment can have an effect on the amount of radiation reaching the target organism. Thus, there may be considerable differences in the dose levels required to prevent hatch of medfly eggs in the different varieties of stone fruits. Nevertheless, despite the need for higher dosages in certain fruits (especially the plum varieties), in all cases, none of the larvae which did hatch survived to develop beyond the first or second larval instar. In fact, most of the larvae died in the first instar or during the moult from the first to the second instar and many dead larvae were observed inside the decaying fruit still encased in the exuvium of the first instar. This observation would appear to indicate that gamma radiation acts by perturbing certain stages of larval development and especially during the moulting process.

We observed similar results in the larval survival studies. That is, mature larvae infesting different varieties of stone fruits required different dosages of radiation to prevent pupation and/or emergence as adults. Again, at the 0.6 as well as the 0.5 kGy dosages, varying rates of pupation occurred depending on the stone fruit variety; however, in all cases, none of the individuals survived to emerge as adults.

Our studies indicate that postharvest treatment with gamma irradiation is certainly a potential alternative to treatment with chemical fumigants such as EDB. However, we recommend that more research be conducted in this area with special emphasis on the condition of the fruit with respect to dosage/mortality determinations. Also, our studies on the Navel oranges (Ohta et al. 1983) indicate that combination treatments, e.g., cold treatment in conjunction with gamma irradiation can have a synergistic effect and this aspect should certainly be investigated for the stone fruits.

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TABLE 1. Hatchability of medfly eggs (from wild strain) oviposited in O'Henry and Fairtime peaches followed by treatment with gamma irradiation.

	Age of Medfly Eggs, Hrs.			
Dose, kGy	24 - 48	48 - 52	68 - 72	72 - 76
	Eggs Hatched/Total Eggs Dissected from Fruit			
Control	190/200 (95.00%)	916/1000 (91.60%)	721/800 (90.13%)	178/207 (85.99%)
0.01	5/248 (2.02%)	—	—	—
0.10	—	40/180 (22.22%)	—	—
0.15	—	3/304 (0.99%)	—	—
0.28	—	1/767 (0.13%)	—	—
0.30	—	0/400 (0.00%)	—	—
0.35	—	—	5/600 (0.83%)	—
0.37	—	—	2/1039 (0.19%)	—
0.40	—	—	0/595 (0.00%)	61/1493 (4.09%)

TABLE 2. Hatchability of medfly eggs (from wild strain) ovipostited in Sun Grand, Larry's Grand, Fairlane, and Autumn Grand nectarines followed by treatment with gamma irradiation.

	Age of Medfly Egg, Hrs.					
Dose, kGy	0 - 4	24 - 28	48 - 52	64 - 68	68 - 72	72 - 76
Control	244/308 (79.22%)	437/541 (80.78%)	291/348 (83.62%)	238/290 (82.07%)	133/163 (81.60%)	259/363 (71.36%)
0.05	—	0/282 (0.00%)	—	—	—	—
0.10	—	0/317 (0.00%)	—	—	—	—
0.25	0/600 (0.00%)	0/400 (0.00%)	3/600 (0.50%)	102/592 (17.23%)	—	—
0.40	—	—	—	—	3/493 (0.61%)	—
0.43	—	—	—	—	—	17/1004 (1.69%)
0.45	—	—	—	—	0/788 (0.00%)	0/844 (0.00%)
0.50	0/497 (0.00%)	0/400 (0.00%)	0/600 (0.00%)	0/532 (0.00%)	—	—

TABLE 3. Hatchability of medfly eggs (from wild strain) oviposited in Casselman plums followed by treatment with gamma irradiation.

	Age of Medfly Egg, Hrs.		
Dose, kGy	24 - 28	48 - 52	72 - 76
	Eggs Hatched/Total Eggs Dissected from Fruit		
Control	126/140 (90.00%)	—	624/713 (87.52%)
0.01	31/400 (7.75%)	—	—
0.10	—	26/123 (21.14%)	—
0.15	—	2/363 (0.55%)	—
0.40	—	—	53/325 (16.31%)
0.50	—	—	20/359 (5.57%)
0.55	—	—	58/284 (20.42%)
0.65	—	—	15/320 (4.69%)
0.70	—	—	10/227 (4.41%)
0.80	—	—	2/182 (1.10%)
0.90	—	—	1/534 (0.19%)

TABLE 4. The buffering effect of water on gamma-radiation and its effect on egg hatchability.

Treatment	# Eggs	# Hatched	% Hatched
"Dry" Control	1000	903	90.30
"Dry" 0.50 kGy	1000	3	0.30
"Wet" Control	1000	908	90.80
"Wet" 0.50 kGy (Distilled Water)	1000	844	84.40
"Wet" 0.50 kGy (Physiological Water)	500	423	84.60

TABLE 5. Hatchability of medfly eggs (USDA strain) oviposited in 8 varieties of nectarines followed by treatment with gamma irradiation.

	Treatment kGy Eggs Hatched/Total Eggs Dissected from Fruit			
Fruit Variety	Control	0.40	0.50	0.60
Sun Grand	823/1000 (82.30%)	701/1500 (46.73%)	879/1500 (58.60%)	8/3498 (0.23%)
Summer Grand	417/500 (83.40%)	512/1500 34.13%)	24/1382 (1.74%)	24/1430 (1.69%)
Red Grand	731/1000 (73.10%)	203/2499 (8.12%)	8/2500 (0.32%)	1/1500 (0.07%)
Niagra Grand	764/1000 (76.40%)	271/1500 (18.07%)	272/1500 (18.13%)	12/3500 (0.34%)
Sam Grand	781/1000 (78.10%)	15/2500 (0.60%)	2/2500 (0.08%)	1/1500 (0.07%)
Autumn Gold	878/1000 (87.80%)	12/2500 (0.48%)	6/2499 (0.24%)	0/1500 (0.00%)
Flamekist	848/1000 (84.80%)	26/1500 (1.73%)	20/1500 (1.33%)	0/1500 (0.00%)
Fairlane	810/1000 (81.00%)	35/3500 (1.00%)	0/1500 (0.00%)	0/1500 (0.00%)

TABLE 6. Hatchability of medfly eggs (USDA strain) oviposited in apricots, cherries and two varieties of peaches followed by treatment with gamma irradiation.

Treatment kGy	Fruit Type/Variety			
	Apricot/ Variety Unknown	Cherry/Burlat	Peach/ Fay Alberta	Peach/O'Henry
	Egg Hatched/Total Eggs Dissected from Fruit			
Control	1218/1700 (71.65%)	1346/1553 (86.67%)	851/1000 (85.10%)	855/1000 (85.50%)
0.40	35/2822 (1.24%)	17/252 (6.75%)	185/1499 (12.34%)	2/2500 (0.08%)
0.50	35/2374 (1.47%)	75/2024 (3.71%)	4/1196 (0.33%)	1/2072 (0.05%)
0.60	24/1926 (1.25%)	6/1959 (0.31%)	8/3174 (0.25%)	0/1070 (0.00%)
0.75	0/1000 (0.0%)	19/2050 (0.93%)	—	—

TABLE 7. Hatchability of medfly eggs (USDA strain) oviposited in five varieties of plums followed by treatment with gamma irradiation.

Treatment kGy	Fruit Variety				
	Laroda	Friar	Casselman	President	Kelsey
	Eggs Hatched/Total Eggs Dissected from Fruit				
Control	812/1000 (81.20%)	814/1000 (81.40%)	812/1000 (81.20%)	607/843 (72.00%)	853/1000 (85.30%)
0.40	263/2500 (10.52%)	47/1500 (3.13%)	681/1500 (45.40%)	14/1500 (0.93%)	256/1500 (17.07%)
0.50	272/2500 (10.88%)	30/1500 (2.00%)	525/1500 (35.00%)	53/1500 (3.53%)	783/1500 (52.20%)
0.60	248/1499 (16.54%)	533/3500 (15.23%)	228/3500 (6.51%)	43/3500 (1.23%)	459/3800 (12.08%)

TABLE 8. Survival rate of mature larvae in eight varieties of nectarines following treatment with gamma irradiation.

Variety	Treatment	# of Larvae Implanted	# Pupated	% Pupated	# Eclosed
Sun Grand	Control	400	255	63.75	238
	0.50 kGy	750	212	28.27	0
	0.60 kGy	750	67	8.93	1 ♂(?)*
Summer Grand	Control	250	201	80.40	184
	0.50 kGy	350	183	21.53	0
	0.60 kGy	850	142	16.71	0
Red Grand	Control	400	292	73.00	277
	0.50 kGy	1100	339	30.82	0
	0.60 kGy	1100	351	31.91	0
Niagara Grand	Control	600	372	62.00	349
	0.50 kGy	1000	275	27.50	0
	0.60 kGy	1000	188	18.80	0
Sam Grand	Control	500	124	24.80	122
	0.50 kGy	1000	210	21.00	0
	0.60 kGy	1000	190	19.00	0
Autumn Gold	Control	550	291	52.91	267
	0.50 kGy	1000	330	33.00	0
	0.60 kGy	1000	175	17.50	0
Flamekist	Control	600	388	64.67	342
	0.50 kGy	1000	204	20.40	0
	0.60 kGy	1000	226	22.60	0
Fairlane	Control	500	293	58.60	257
	0.50 kGy	1000	248	24.80	0
	0.60 kGy	1000	239	23.90	0

*See text for explanation.

TABLE 9. Survival rate of mature larvae in apricots, cherries and 2 varieties of peaches following treatment with gamma irradiation.

Variety	Treatment	# of Larvae Implanted	# Pupated	% Pupated	# Eclosed
Apricots/Unknown	Control	495	246	49.70	220
	0.50 kGy	1200	154	12.83	0
	0.60 kGy	1200	168	14.00	0
Cherries/Burlat	Control	618	401	64.89	0
	0.50 kGy	200	53	26.50	0
	0.60 kGy	550	71	12.91	0
Peaches/Fay Alberta	Control	350	161	46.00	116
	0.50 kGy	1100	246	22.36	0
	0.60 kGy	1100	259	23.55	0
Peaches/O'Henry	Control	450	232	51.56	206
	0.50 kGy	1000	217	21.70	0
	0.60 kGy	1000	115	11.50	0

TABLE 10. Survival rate of mature larvae in five varieties of plums following treatment with gamma irradiation.

Variety	Treatment	# of Larvae Implanted	# Pupated	% Pupated	# Eclosed
Laroda	Control	420	165	39.29	146
	0.50 kGy	1170	166	14.19	0
	0.60 kGy	1080	121	11.20	0
Friar	Control	510	59	11.57	54
	0.50 kGy	1020	92	9.02	0
	0.60 kGy	1020	144	14.12	0
Casselman	Control	510	0	0.00	—
	0.50 kGy	1020	15	1.47	0
	0.60 kGy	1020	31	3.04	0
President	Control	450	7	1.56	6
	0.50 kGy	1020	15	1.47	0
	0.60 kGy	1020	3	1.28	0
Kelsey	Control	570	169	29.65	143
	0.50 kGy	1020	99	9.71	1 ♀(?)*
	0.60 kGy	1020	62	6.08	0

*See text for explanation.

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